

REMARKS

This application has been carefully reviewed in light of the Office Action dated December 17, 2003. Claim 1 has been amended. A Petition for Extension of Time (one-month) is being filed concurrently herewith. Applicants respectfully request reconsideration of the above-referenced application in light of the amendments and following remarks.

Claims 1-3, 6-16, 18, 21-31, and 34-45 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Wang in view of Hoff or Ruzyllo. The rejection is respectfully traversed.

Claim 1 recites “[a] method of forming a flash memory cell, comprising: forming a tunnel oxide . . . forming a first conductor layer . . . forming an insulating layer . . . comprising a first oxide layer over said first conductor layer, a nitride layer over said first oxide layer, and a second oxide layer over said nitride layer, said second oxide layer grown by oxidizing said nitride layer with a gas ambient containing atomic oxygen for about 1 second to about 10 minutes, wherein said second oxide layer is formed to have a thickness of at least 60% of the targeted thickness of the second oxide layer, and wherein said second oxide layer is formed to a thickness of about 20 Å – 80 Å.”

Claim 16 recites “[a] method of forming an ONO insulating structure, comprising: depositing a first oxide layer . . . depositing a nitride layer over said first oxide layer; and growing a second oxide layer over said nitride layer wherein said second oxide layer is grown at a temperature of about 850°C to about 1100°C, for about 1 second to about 10 minutes, using a gas ambient containing atomic oxygen, wherein said second oxide layer is formed to a thickness of about 20 Å – 80 Å.”

Claim 31 recites “[a] method of forming a flash memory array containing a plurality of flash memory cells, each of said plurality of flash memory cells being formed by the acts of: forming a tunnel oxide . . . forming a first conductor layer . . . forming an insulating layer over said first conductor layer, said insulating layer comprising a first oxide

layer over said first conductor layer, a nitride layer over said first oxide layer, and a second oxide layer over said nitride layer, wherein said second oxide layer is grown in the presence of atomic oxygen at a temperature of less than about 900°C for a period of about 1 second to 10 minutes.”

The Office Action asserts that Wang teaches that the “second oxide layer is formed by oxidizing said nitride layer with an ambient containing atomic oxygen to a thickness of 50 angstroms.” (Office Action, pg. 2) (emphasis added). Applicants respectfully disagree. Wang does not teach or suggest that ‘atomic oxygen’ is used to form the second oxide layer.

Wang provides a method “for reducing the gate aspect ratio of a flash memory device . . . [by using] nickel silicide instead of the conventional tungsten silicide in the control gate layers of the cells of the device,” (Col. 4, lines 42-45) (emphasis added) and merely teaches a conventionally-formed ONO structure. Wang teaches that the “second of the two oxide layers of the dielectric layer 410 is formed using a nitride oxidation technique at about 950°C. with about 5 liters of O₂ and 9 liters of H₂ for about 40 minutes, which grows approximately 50 Å of oxide.” (Col. 3, lines 49-54) (emphasis added). In other words, Wang merely teaches a conventional way of forming an ONO structure.

In contrast, Applicants teach that the methods of the claimed invention yield a “resulting oxide layer [which] will be at least about 60% of the targeted thickness of the top oxide layer on the nitride layer 46b as compared to a typical thickness of about 1% to 3% of the targeted thickness in a conventional method, such as wet oxidation, not utilizing atomic oxygen.” (Applicants’ specification, pg. 13, lines 13-19).

The difference between Applicants’ claimed methods and Wang are underscored by the fact that Wang’s resulting ONO structure is only 135 Å thick. Wang teaches an ONO stack comprising a first oxide layer 50 Å thick, the nitride layer 80 Å thick, and the second oxide layer is formed using a conventional nitride oxidation technique (See Col. 3, lines 44-52). The resulting ONO structure is only 135 Å (Col. 3, lines 53-54). Thus,

Wang's top oxide layer results in an actual thickness of 5 Å to form a 135 Å thick ONO stack versus Applicants' claimed 20-80 Å thick top oxide layer.

In addition, the prior art of record does not teach or suggest that the thickness of the nitride layer is reduced as a result of employing a nitride oxidation technique. In fact, in the Discussion of the Related Art of Applicants' specification, it is well-known that a conventional nitride oxidation process in forming an ONO stack, such as taught in Wang, the top oxide layer will only achieve a small percentage of the desired thickness. For instance, if 50 Å of a top oxide layer is grown, only 3-5 Å will result (See Applicants' specification, pg. 5) This is the exact problem that Applicants' claimed methods are directed to solving, i.e., the conventional process disclosed in Wang.

Employing Applicants' claimed methods result in a top oxide layer that is 60% of the targeted thickness. Although Wang may disclose attempting to grow a top oxide layer 50 Å thick, the resulting top oxide layer is only 5 Å thick. Again, in the Discussion of the Related Art of Applicants' specification, it discloses that "the top oxide layer of an ONO interpoly dielectric layer is conventionally formed by a high temperature, wet oxidation process. Such a process involves oxidizing the nitride layer in steam and oxygen at high temperatures of about 950 °C, for a long duration of time." (Applicants' specification, pg. 5, lines 13-15) (emphasis added).

Wang teaches a long duration: 40 minutes. Wang teaches a high temperature: 950°C. Wang teaches nitride oxidation: a conventional technique not using atomic oxygen. As a result, Wang discloses a method of forming a conventional ONO structure. If this were not the case, Wang's ONO stack would be 180 Å thick rather than 135 Å thick.

The Office Action further asserts that both Hoff and Ruzyllo "disclose forming an oxide layer . . . using an oxidizing method with atomic oxygen," and concludes that it would have been obvious to modify the process of Wang "so as to form the second oxide

layer using the process taught by Hoff et al. or Ruzyllo et al. because both of these processes allow for oxide growth at low temperatures with high breakdown values.” (Office Action, pg. 3).

The Office Action asserts that the motivation to combine the references stems from the fact that “these processes allow for oxide growth at low temperatures with high breakdown values.” (Office Action, pg. 3). However, Wang teaches forming the top oxide layer with nitride oxidation at a temperature of 950°C. This is not a low-temperature process. There is no motivation to combine the references.

Moreover, the cited references teach away from each other. For instance, in Ruzyllo, the article discloses that “[t]he application of nitrogen as an oxygen diluent results in the degradation of oxide properties in terms of fixed oxide charge density and dielectric strengths.” (Summary of Ruzyllo, pg. 378) (emphasis added). Wang discloses a nitride oxidation technique and thus, the presence of nitrogen would degrade Wang’s ONO stack.

The Office Action asserts that “it would have been obvious to determine through routine experimentation the optimum time and temperature to conduct the oxidation process.” (Office Action, pg. 3). However, no support has been provided for this assertion. In other words, the combination of cited references simply do not teach or suggest Applicants’ claimed temperature or time for forming the top oxide layer using atomic oxygen. Wang clearly teaches a nitride oxidation time of at least 40 minutes. This is four times as long as Applicants’ claimed atomic oxidation process. This is a significant difference in process parameters.

Claims 2-3 and 6-15 depend from claim 1, claims 18 and 21-30 depend from claim 16, and claims 34-45 depend from claim 31. These claims are at least allowable for the reasons set forth above regarding independent claims 1, 16, and 31.

In view of the above, each of the presently pending claims in this application is believed to be in immediate condition for allowance. Accordingly, the Examiner is respectfully requested to pass this application to issue.

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Respectfully submitted,

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